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The role of communication in fair division with subjective claims☆

Anita Gantner[a,*], Kristian Horn[b], Rudolf Kerschbamer[c]

[a] *Department of Economics, University of Innsbruck, Universitätsstr. 15, Innsbruck, 6020 Austria*
[b] *Austrian National Bank, Austria*
[c] *University of Innsbruck, Austria*

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When agents' claims regarding the division of a cake are subjective and conflicting, it is difficult to obtain an outcome that is considered fair by the involved parties. This paper investigates how pre-play communication affects behavior and outcomes in fair division experiments where various procedures are used to obtain an allocation of the available resources. On the one hand, it is known from bargaining experiments that communication often leads to faster agreements and to more egalitarian allocations. On the other hand, communication may facilitate the emergence of minority-exploiting coalitions when procedures are used which are not collusion-proof. We find that communication increases both efficiency and perceived fairness of the implemented division independent of the procedure used to obtain a solution. Interestingly, collusion, while highly beneficial for those participating, is rarely attempted even when private communication channels are available.

1. Introduction

This paper provides stark and robust evidence for the positive role of communication in fair division problems with subjective claims. In fair division problems the aim is to find a way of dividing a given resource among several partners in such a way that all partners believe that they have received a fair amount, according to some notion of fairness (see Brams, 2008). Applications range from the allocation of natural resources and money, over the optimal division of labor and voting power, to conflicts over intellectual property rights, to name just a few. The present study focuses on fair division problems with subjective claims where the possibly conflicting perceptions of the parties on how the resource should be divided fairly arise from different contributions of the parties to the jointly produced cake.

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* Corresponding author.
E-mail address: anita.gantner@uibk.ac.at (A. Gantner).

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We have two companion papers which compare the performance of different procedures used to reach a consensus in a three-person fair division problem with subjective claims when communication possibilities are absent.[1] One paper investigates the fairness and efficiency of three (static) mechanisms which use partners' reports on fair shares as input and yield a division of the cake (or less) as output, and the other paper compares the performance of three unanimity bargaining procedures in the same setting. The present paper is a natural extension of the two companion papers; it examines the impact of cheap talk communication on the fairness and efficiency of the three mechanisms from the Gantner and Kerschbamer (2016) paper and the best performer of the bargaining procedures from Gantner et al. (2016).[2]

A priori it is not clear whether cheap talk is good or bad for fairness and efficiency in a fair division problem with subjective claims: On the one hand, it is known from bargaining experiments that communication often leads to faster agreements and to more egalitarian allocations (see, e.g., Bohnet and Frey, 1999; Charness and Rabin, 2005; Andreoni and Rao, 2011). On the other hand, communication may facilitate the emergence of minority-exploiting coalitions when procedures are used which are not collusion-proof (see Tideman and Plassmann, 2008, for instance).

In this study, we investigate which direction the effect of communication takes in the three fair division mechanisms and the bargaining procedure described above. More precisely, we seek to answer the following main research questions: (1) Does pre-play communication help to resolve problems of fair division by leading to a convergence of agents' claims, or does it foster collusion and self-serving behavior? (2) How does the type of the communication channel available (i.e. public vs. private communication) affect behavior and outcome? (3) How does the content of communication affect behavior and outcome? (4) How does the answer to these questions depend on the procedure used to obtain an allocation?

To address these questions, we generate a three-player fair division problem with subjective claims in the experimental lab, where agents' claims are derived from individual efforts. Each three-player partnership is then exposed to the four procedures described above which are used to obtain a division of the joint profit in our experiment. Before entering a decision, subjects may communicate via computer chat. In different treatments we vary the available communication channel: In `NOCOM` communication is not possible, in `PUBLIC` subjects can only chat with both partners simultaneously, in `PRIVATE` subjects have a separate chat windows for each partner, and in `CHOICE` both private and public chat windows are available.

In a nutshell, our main findings are that (i) communication in the subjective claims problem increases the efficiency and perceived fairness of outcomes under all procedures considered, with rather small differences across the communication protocols; and (ii) contrary to theoretical concerns, collusion plays at best a minor role, although it is highly effective when agents have the possibility to talk in private. The chat data suggest that when private communication channels are used, feelings of empathy are replaced by more selfish concerns, so that subjects tend to propose divisions corresponding to the fairness norm which is most beneficial for them. Predominantly, however, subjects display pro-social behavior and given a choice of communication channels (in `CHOICE`), they use public communication that includes all partners. This supports the idea that subjects try to maintain a positive self-perception and social image (Dana et al., 2007; Andreoni and Bernheim, 2009; Andreoni and Rao, 2011). The chat dynamics analysis shows that the first proposal in a chat is decisive for the group agreement. About three quarters of the groups agree on the first proposal, no matter its shape. Proposals that are unequal but reflect the partners' contribution order find more resistance in the group decision compared to egalitarian proposals.

Our results have several parallels in the previous literature: First, our results have close relatives in the large and still growing literature on the effects of communication on agreements in social conflict situations.[3] For various types of experimental games pre-play communication has been found to facilitate agreement und to lead to more egalitarian outcomes, in the sense that payoffs equalize initial status or endowment differences between players, rather than reinforcing such differences (see, e.g., Farrell and Rabin, 1996; Charness, 2012). These findings are completely in line with our main result that communication induces a remarkable increase in efficiency and in the conformity of realized payoff shares with known fairness standards – in particular with the egalitarian standard.

When bargaining is used as allocation procedure, the literature offers different possible explanations for the so-called "communication effect" – that is, for the result that communication facilitates agreement and leads to more egalitarian outcomes.[4] Communication may improve coordinated common action, facilitate understanding of the game, promote common knowledge regarding preferences and beliefs, underline the presence of shared values, i.e. of social and fairness norms, and provide a salient group identity (Bicchieri, 2002; Bicchieri and Lev-On, 2007; Cason et al., 2012). Among economists, group identity seems to be the most influential explanation (Akerlof and Kranton (2000)).[5] It has been found to shift the interest of each member from the individual to the group level (Leibbrandt and Sääksvuori, 2012; Cason et al., 2012). This,

[1] See Gantner and Kerschbamer (2016) and Gantner et al. (2016).

[2] The present paper also complements the studies by Gächter and Riedl (2006) and Karagözoglu and Riedl (2014). While in the former paper the subjective entitlements come from infeasible objective claims, in the latter they arise because there is only ordinal information on the partner's contributions. In contrast to the present paper and to Gantner and Kerschbamer (2016) and Gantner et al. (2016) these studies focus on two-person fair division problems.

[3] For an early survey on the impact of cheap talk in different games see Crawford (1998). Balliet (2010) and Sally (1995) provide meta-analyses for various types of social dilemmas.

[4] Not all papers confirm the existence of all facets of the communication effect: Valley et al. (2002) show that pre-play communication increases efficiency of bargaining in a private information context; however, the hypothesis that communication results in a more equal distribution of the surplus is not supported by the data.

[5] Also see the seminal study by Tajfel et al. (1971) in social psychology.

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in turn, tends to lead to faster agreements and to more egalitarian outcomes (Charness et al., 2007; Chen and Li, 2009).[6] McGinn et al. (2012) show that the communication effect is shaped by the content of messages: If reasoning is competitive, this leads to more unequal divisions, while talk about fairness drives divisions towards an equal split of the surplus.[7] Our results confirm the importance of the content of communication – and additionally, they show that the timing of an argument is important as well. Specifically, our data suggests that the first proposal in a chat is decisive for the final agreement, no matter its shape.

The vast majority of papers that study the effects of communication on bargaining behavior focus on bilateral bargaining. Exceptions are Bolton et al. (2003), McGinn et al. (2012), and Agranov and Tergiman (2014), all of which study multilateral coalitional bargaining. The latter study concludes that the communication effect found in bilateral settings, which leads to a more equal distribution, does not extend to multilateral ones. By contrast, our study provides strong evidence that communication leads to a larger share of egalitarian outcomes even in a multilateral bargaining environment. The discrepancy in results might well be due to the fact that in their coalitional bargaining environment a majority can impose its will on the minority. By contrast, we require unanimity in our bargaining game, since we are interested in an outcome that provides a fair solution for all agents involved.

The fact that in our environment communication potentially has an ambiguous effect on fairness and efficiency has some parallels in the literature investigating tournaments between teams. When teams, rather than individuals, compete for a prize there is a need for intra-team coordination in order to win the inter-team competition. In such an environment communication may have an ambiguous effect on efficiency: communication within teams may increase effort provision by mitigating internal free-rider problems (as in the public-goods environment studied by Sutter and Strassmair (2009)) or internal miscoordination (as in the weakest link game investigated by Cason et al. (2012)), while communication between competing teams may decrease wasteful effort. We discuss the relation to this literature and its findings in more detail in the results section.

Our main result that communication increases the efficiency and perceived fairness of outcomes and does not lead to exploitation of minorities through collusion has an important parallel in Sheremeta and Zhang (2014): In a three-player trust game, the authors find that communication between two players increases their preference for fairness rather than collusive behavior, and this seems to be anticipated by the third player, as his trust level increases.

We procced as follows: Section 2 introduces our fair division problem with subjective claims as well as the tested allocation procedures. Section 3 presents the experimental design and our benchmark measures regarding the fairness of claims and allocations. Section 4 covers the main results of the experiment, Section 5 describes the results of an extensive chat content analysis, and Section 6 concludes.

2. Fair division with subjective claims

2.1. Subjective claims problem

Consider a problem of fair division where three partners A, B, and C each have exerted effort that determines their individual contribution towards a cake of size S. While contributions to the cake are observable, they have been earned in different environments, implying that partners might not be willing to base their fairness assessments on contributions. Contributions enter a production function in a non-linear way, such that their combined value is higher than the sum of the stand-alone values. Thus, it is likely that the partners have conflicting subjective evaluations about whether a division $\mathbf{s} = (s_A, s_B, s_C)$ of S is fair. In the following, we will refer to a division of the cake that is considered fair by partner i as i's *subjective evaluation of claims* $\mathbf{c^i} = (c^i_A, c^i_B, c^i_C)$, where c^i_j stands for the payoff share partner j should receive from agent i's perspective and where $c^i_A + c^i_B + c^i_C = S$.[8]

We will compare the impact of communication on the performance of four different procedures to divide the cake – three static mechanisms, where a given rule maps agents' reports into a unique division allocation, and one unanimity bargaining protocol. The three mechanisms ask agents to report evaluations of claims and they differ in the kind of information they ask for. When agent i is asked to report an evaluation of agent j's fair share, we denote the respective report by m^i_j. For the bargaining procedure we ask each subject to make an initial allocation proposal which becomes binding when the subject is assigned the role of player 1 in the bargaining game. Here, m^i_j denotes the share agent i assigns to agent j in the initial proposal, while we will refer to m^i_i as agent i's initial own claim.

For a given procedure, the vector $\mathbf{s} = (s_A, s_B, s_C)$ gives the realized payoff shares, whereas $\mathbf{m} = (m^A_A, m^B_B, m^C_C)$ refers to the vector of the initial own claims. Division allocations and claims are evaluated in terms of efficiency and allocative fairness. The efficiency evaluation is made in terms of the fraction of S that is finally paid out to the partners. For the fairness

[6] While our focus is on situations where a group has to make an allocation decision that affects only the group members, the literature on team decision making studies environments where a group has to make a decision that affects other groups or individuals as well. In the latter context teams tend to be more selfish and follow more closely rational behavior as predicted by standard game theory (Charness and Sutter (2012)).

[7] Croson et al. (2003) were among the first to analyze how contents of cheap talk, such as responders' lies and threats, affect outcomes in ultimatum games.

[8] To simplify comparisons over different cake sizes, we will use normalized shares with $c^i_A + c^i_B + c^i_C = 1$ later on.

assessments, we use a partial fairness benchmark, which draws on reported subjective evaluations of claims, as well as two known fairness norms as yardsticks.

2.2. Fair division procedures

DeClippel et al. (2008) describe a mechanism – referred to as the Impartial Division Rule – which has three desirable properties: impartiality, consensuality, and strategy-proofness. Impartiality refers to the property that an agent's share is determined exclusively by the reports of the other agents. Consensuality requires that if there is a way to divide S that agrees with all individual reports, then this is the outcome. Finally, strategy-proofness here means that no agent is able to increase his own share through a dishonest report. The Impartial Division Rule is the first mechanism we describe and analyse below. In a study that focuses on the properties of the Impartial Division Rule, Tideman and Plassmann (2008) refer to two other mechanisms that are potentially applicable to this kind of fair division problem with subjective claims: the Extended Divide-the-Dollar Rule introduced by Brams and Taylor (1994), and the Modified Nash-Demand Rule proposed by Mumy (1981). Both of these rules use the idea of penalizing agents when the sum of the own claims exceeds S. In addition to these three static mechanisms, we also include a bargaining procedure proposed by Sutton (1986) in our comparison.

Impartial Division Rule. The Impartial Division Rule by DeClippel et al. (2008) asks each partner i for an assessment of the ratio m^i_j/m^i_k, i.e. each player i is asked what his partner j should receive, relative to his other partner k. Payoffs shares are then determined as follows: $s_A = S/(1 + m^B_C/m^B_A + m^C_B/m^C_A)$; $s_B = S/(1 + m^A_C/m^A_B + m^C_A/m^C_B)$; $s_C = S/(1 + m^A_B/m^A_C + m^B_A/m^B_C)$. If there is a division of the cake, which is consistent with the three relative assessments, this division is implemented. Otherwise, the rule divides less than S, and the inefficiency increases in the degree of inconsistency. Although this rule has several desirable properties (as discussed above), it also has a distinctive disadvantage – it is susceptible to collusion: If two partners agree to both undervalue the third partner's share, they profit at the expense of the third partner. Tideman and Plassmann (2008) show that it is not possible to modify this rule in a way such that it becomes collusion proof. One of our treatments – the private communication protocol – offers the opportunity to investigate how severe the collusion problem is under this rule.

Extended Divide the Dollar Rule. The Extended Divide-the-Dollar Rule by Brams and Taylor (1994) asks each player i to report a complete division of S – an own claim m^i_i for himself, as well as m^i_j and m^i_k for his partners. In case the vector of initial own claims is feasible, meaning $\sum_i m^i_i \le S$, the claims are paid out. Otherwise, payoffs depend on the players' greed level. A partner's greed level is computed as the difference between player i's own claim, m^i_i, and the average of the assignments to this partner by the other two members of the group, $(m^j_i + m^k_i)/2$. The player with the lowest greed level receives his claim first, while the others follow sequentially, until the cake is depleted. Under this mechanism an inefficiency arises if and only if own claims sum up to less than S. It is important to note that this mechanism is also susceptible to collusion: If two partners agree to assign a low share to the third partner, this increases the greed level of that partner, which may allow the two colluding agents to ensure larger shares for themselves.

Modified Nash Demand Rule. In the Modied Nash Demand Rule by Mumy (1981) each player is only asked for an assessment of the own claim m^i_i. Payoff shares are then determined by the following rule: $s_i = m^i_i - \max\{a(\sum_i m^i_i - S), 0\}$, where $a > 1$. If the sum of own claims does not exceed the available cake, each player receives a share equal to his own claim. Otherwise each player is fined with a multiple of the difference between the cake and the sum of own claims. Consequently, two types of inefficiencies may arise under this procedure: one from claiming too little, and one from claiming too much. This mechanism has little potential for collusion, since each partner is asked only for an assessment of the own fair share, and excess claims lead to a fine for *all* partners. Since inefficiencies under this procedure are likely to be due to coordination failure, one may expect communication to have positive effects.

Shaked's Unanimity Bargaining Rule. In the unanimity bargaining rule due to Shaked (see Sutton 1986), players take turns in making complete division proposals $m = (m_1, m_2, m_3)$, where m_i is the share proposed for player i and $\sum_i m_i = S$. Player 1 makes the first proposal in round $t = 1$. Player 2 and player 3 then respond sequentially, each either accepting or rejecting the proposal. If both responders accept, then the proposed allocation is implemented. In case of a rejection, the game proceeds to round $t = 2$, where player 2 makes a proposal and players 3 and 1 sequentially respond. Again, if one of the responders rejects, then the next round begins with now player 3 making an offer, and so on. There is no exogenous termination round, and payoffs are discounted by the common discount factor δ. Due to discounting an inefficiency arises if agreement is delayed. On the other hand, since all partners have to agree to a given allocation, the potential for minority-exploiting coalitions is limited.

3. Experimental design

3.1. Treatments and subject sample

We study the role of communication in the subjective claims problem by varying the available pre-play communication channels over four treatments. While in our control treatment NOCOM communication is not possible, all other treatments feature a chat phase of three minutes via computer between reading the instructions and playing the respective allocation procedure. We distinguish between the following three communication channels: In treatment PUBLIC, subjects can only

Table 1
Benchmark measures over group composition and contribution types.

Contribution type		*Egalitarian share*	*Proportional share*	*Avg. fair share*
LML				
Low	2 pts.	0.333	0.286	0.314
Medium	3 pts.	0.333	0.429	0.373
MLH				
Low	2 pts.	0.333	0.222	0.264
Medium	3 pts.	0.333	0.333	0.331
High	4 pts.	0.333	0.444	0.405
HHM				
Medium	3 pts.	0.333	0.273	0.288
High	4 pts.	0.333	0.364	0.356

Note: avg. fair share is the mean of subjects' responses to the fairness question.

chat with both partners simultaneously, i.e., all messages are displayed to both partners. In treatment PRIVATE, subjects have a separate chat windows for each partner, which makes private conversations possible. In CHOICE, finally, both private and public chat windows are available, such that subjects can choose their preferred channel at any time. The treatment variable *communication* is between-subject, i.e. each subject participated in exactly one of the communication treatments. The treatment variable *procedure* is within-subject, i.e. all subjects were exposed to the four fair-division procedures described above.

The experimental sessions were programmed and conducted with the software z-Tree (Fischbacher, 2007) at the Innsbruck-EconLab for experimental economic research. Recruitment was done using ORSEE (Greiner, 2015). A total of 792 undergraduate and graduate students from all majors participated in the four treatment groups, and assignment of subject to treatment groups was random. Sessions lasted for approximately 60 minutes. Average earnings were EUR 13.70 per subject.

3.2. Experimental procedure

Real effort task. A total of 18 subjects participated in each session. After entering the lab, subjects were randomly assigned to one of three cohorts, each consisting of 6 subjects, to perform a real effort task. In this task, subjects were asked to correctly answer as many general-knowledge questions as possible within a given time period. They were informed that each subject in a cohort would receive points depending on her relative performance within her cohort: the two high performers receive 4 points, the two medium performers 3 points, and the two low performers 2 points. In the analysis below we will refer to these as high, medium, and low *contribution types*.

Cake production and division. After the quiz, partnerships consisting of three subjects labelled *A, B, C*, each coming from a different cohort, were formed. The points a subject has earned in the real effort task is the contribution of this subject towards the partnership. Subjects were informed about the number of questions they answered correctly, their own rank within their cohort, and the points they achieved. Furthermore, they were informed about the points each partner contributed and the resulting cake size S of their partnership.[9] Subjects also knew the non-linear production function determining the size of the jointly produced cake:

$$S = 12 + (points\ A) \cdot (points\ B) \cdot (points\ C)$$

In our experiment, we test to three different group compositions: groups with two low and one medium contribution types (LML) dividing a cake size of $S = 24$; groups where all partners are of different contribution types (MLH) dividing a cake size of $S = 36$; and groups with one medium and two high contribution types (HHM) dividing a cake size of $S = 60$ (refer to Table 1 for an overview).[10,11] Before the actual division of S, each participant's subjective evaluation of claims was elicited in a hypothetical fairness question (see below). Then subjects were successively exposed to each of the four division procedures described above, without having any feedback regarding the outcome of any previous procedure.[12] In the treatments that featured a chat phase, communication occurred after answering the fairness question but before entering the required decisions for each procedure. In the bargaining procedure, all subjects were asked to submit a proposal. They were informed that their proposal would be used as the actual initial proposal in case the subject was assigned the role of player 1 in the first bargaining round. The discount factor we used was $\delta = 0.9$.[13] For the Modified Nash-Demand Rule, the

9 Since partners earned their points in different cohorts, partners who bring in the same contribution in points may well have performed differently in terms of correctly answered questions.

10 For simplicity, we label the group composition so that it represents the order of players' moves in the first round of the bargaining game; e.g. in MLH, player 1 in round 1 will be a medium contributor (M), player 2 a low contributor (L) and player 3 a high contributor (H).

11 Regarding possible cake size effects, we refer to the study by Karagözoglu and Riedl (2014), who did not find effects of cake size on the main bargaining variables.

12 Bargaining was always the last procedure in the sequence, since outcomes are known upon agreement.

13 We also tried out a discount factor of $\delta = 0.8$ in some separate sessions, but this did not affect behavior in any significant way.

punishment factor a determining the fine in case reported own claims exceed S was set to 1.1. A subject's total payoff is the sum of the points earned in each division procedure, where each point paid EUR 0.25. Information on realized outcomes was provided only at the very end of the experiment.

Fairness question and benchmark measures. In the fairness question, which was presented before any division procedure was introduced, subjects were privately asked what they would consider a fair division of the jointly produced cake. This report was not payoff relevant and we interpret it as subjects' subjective evaluation of claims, $\mathbf{c^i} = (c^i_A, c^i_B, c^i_C)$. We refer to c^i_i as partner i's *own fair share*, and to the mean share partner i is assigned from all three partners, $c^{avg}_i = (c^A_i + c^B_i + c^C_i)/3$, as i's *avg. fair share*. For the purpose of immediate comparison across cake sizes, all payoff shares and claims are displayed as fractions of cakes size S. Since we expect a self-serving bias in c^i_i, we will use c^{avg}_i as one of our benchmarks to assess the fairness of a given allocation. This benchmark reflects a de-biased partial fairness view, as it represents the views of stakeholders, but does not only take into account one's own evaluation but also that of the other partners in a group.[14] To quantify the suspected self-serving bias distorting the inputs of subjects for three mechanisms and the bargaining procedure, we will use the difference between a subject's initial own claim m^i_i and c^{avg}_i.

As a further benchmark we will use well-known fairness norms. Specifically, we refer to the *egalitarian standard* when S is distributed equally among the partners, and to the *proportional standard* when shares of S are assigned proportionally to the points each partner has contributed. We will compare the norms to initial claims as well as to final outcomes.[15] Table 1 summarizes our benchmark measures for each contribution type and group composition.

4. Experimental results

4.1. The impact of communication on realized outcomes

To obtain a first general impression of the communication effects in the fair division problem, Panel A of Fig. 1 plots the average payoff shares across procedures (*avg. payoff*) as well as the fairness benchmarks *avg. fair share* and *proportional* share for each contribution type and each communication protocol. We observe the following: (i) In NOCOM, all contribution types receive less than what *avg. fair share* suggests; this implies an efficiency loss in the various procedures, since $\sum_i c^{avg}_i = 1$.[16] (ii) There are no differences in *avg. payoff* across the treatments with communication. (iii) Independent of the available communication possibilities, communication increases the *avg. payoff* for low and medium contributors compared to NOCOM, while that of high contributors remains roughly unchanged; as a result, efficiency is increased and the spread in payoffs for the different contribution types is reduced in the communication treatments. (iv) Compared to the *proportional* standard, realized payoffs and fair shares display a less extreme distribution: while for low contributors both *avg. fair share* and *avg. payoff* are strictly larger than the share implied by the *proportional* standard, they are smaller for medium and high contributors – without violating the contribution order. (v) In contrast to NOCOM, low and medium contributors' *avg. payoff* is at least as high as *avg. fair share* in all treatments with communication, while it continues to be lower for high contributors.

For a more detailed picture regarding the impact of communication possibilities on the observed payoff shares, Table 2 reports for the various communication protocols the difference between the realized payoff share s_i and the *avg. fair share* c^{avg}_i. Separate regressions are run by contribution type (middle panel) and division procedure (lower panel). First, pooling over all procedures and contribution types, we find that the mean absolute deviation $|s_i - c^{avg}_i|$ in NOCOM is almost twice as large as in each of the communication treatments. As indicated, this treatment effect is highly significant and also holds for each contribution type alone (middle panel). We interpret this as an improving effect of communication, since for all contribution types payoff shares are closer to the de-biased partial fairness view when pre-play communication is possible.

The lower panel of Table 2, where we separate by procedure, shows a similar picture: With communication, the deviation from the *avg. fair share* generally decreases in all procedures. However, there are some differences across procedures, which have to be evaluated in the context of the procedures' performance in NOCOM: The Modified Nash Demand Rule exhibits the largest decrease in this deviation (significant for all comparisons), indicating that pre-play communication can overcome the substantial inefficiency found in NOCOM for this procedure. We also observe some improvement for the Extended Divide-the-Dollar Rule, while the deviation for the Impartial Division Rule is smaller and only significant in PUBLIC. For the Unanimity Bargaining Rule the deviation of s_i from c^{avg}_i is already fairly small in NOCOM, and we do not find a significant effect of communication on the fairness of payoff shares.[17]

As another measure of the communication effect on realized outcomes, we compute the average Spearman correlation coefficient ρ between s_i and c^{avg}_i over all contribution types and mechanisms. Compared to NOCOM (ρ=0.51) we see a large

[14] In fact, one important finding in Gantner et al. (2016) is that the de-biased partial fairness view, as represented in the *avg. fair share* from our fairness question, points toward the same allocation as the impartial fairness assessment of neutral spectators in a complementary vignette study.

[15] If a certain fairness norm does not predict integers, we expect some rounding of subjects, even if they comply with this norm. To account for that in the classification of the mechanisms' initial claims as well as final outcomes, we allow for intervals which round to the next half unit.

[16] As shown in Gantner et al. (2016), the efficiency loss is particularly severe for the Modified Nash Demand Rule where about 25% of the cake is lost.

[17] These results are robust to estimating the communication effect separately for contribution type in each mechanism (see Table A.1 in the appendix).

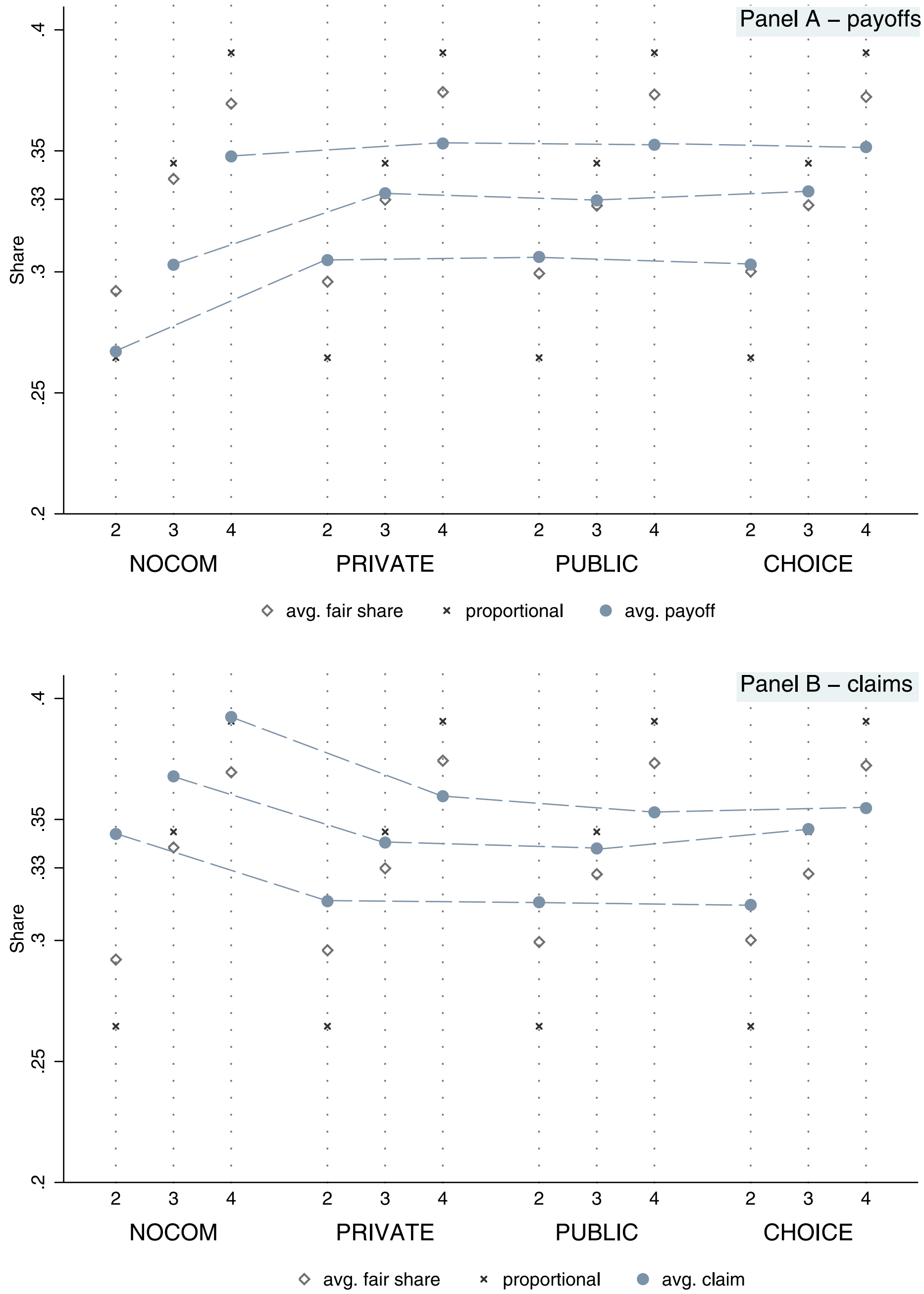

Fig. 1. Payoffs and initial claims by contribution type and treatment *Note*: The dashed lines depict the means over procedures of payoff shares (Panel A) and initial own claims (Panel B) for each contribution type (2=low, 3=medium, 4=high) and treatment. Proportional shares and average fair shares from the fairness question are included as benchmarks.

increase in ρ in all communication treatments ($0.69 \leq \rho \leq 0.75$).[18] Finally, in a pairwise comparison, s_i and c_i^{avg} are significantly different only in NOCOM (Wilcoxon signed-rank test: $p < 0.001$).[19]

These results are confirmed by a regression analysis (see Table A.2 in the appendix) showing that on the one hand, c_i^{avg} has a significant impact on the dependent variable s_i for each procedure tested (controlling for contribution type) in all communication treatments, but not in NOCOM. On the other hand, the decreasing payoff differences in the communication

[18] The correlation coefficient in NOCOM is comparable to that reported by Gächter and Riedl (2005) for the effect of hypothetical fairness judgments on actual divisions in a two-player bargaining game.

[19] The *avg. fair share* does not differ across treatments (Kruskal-Wallis test: $p = 0.90$).

Table 2
Deviation of realized payoff share s_i from fairness benchmark *avg. fair share* c_i^{avg} across communication treatments (in % of cake size).

	NOCOM	PRIVATE	PUBLIC	CHOICE
POOLED ANALYSIS				
Mean deviation $\|s_i - c_i^{avg}\|$	6.12	3.30 ***	3.60 ***	3.63 ***
Spearman's ρ (s_i, c_i^{avg})	0.51	0.75	0.69	0.72
BY CONTRIBUTION TYPE				
Mean deviation $\|s_i - c_i^{avg}\|$				
Low	6.54	3.14 ***	3.90 ***	3.35 ***
Medium	6.24	3.53 ***	3.39 ***	4.25 ***
High	5.57	3.24 ***	3.52 ***	3.30 ***
BY PROCEDURE				
Mean deviation $\|s_i - c_i^{avg}\|$				
Impartial	5.23	4.01	3.70 **	4.05
Divide $	5.38	3.10 **	3.37 **	3.45 *
Nash Dem.	10.31	3.24 ***	4.09 ***	3.91 ***
Barg.	3.54	2.85	3.25	3.13

*** (**) [*] indicates that the comparison to NOCOM is significant at 1% (5%) [10%] level in OLS regression with mean absolute deviation as dependent variable, controlling for cake size and contribution type, or mechanism, respectively; robust SE are clustered on the group level.

treatments suggests that the impact of the differences in subjects' claims derived from their differing contributions decreases with communication. We summarize the findings regarding realized payoffs as follows.

Result 1. When pre-play communication is introduced, payoff differences between contribution types diminish and efficiency increases in all procedures, irrespective of the type of communication channel available. Final allocations in all procedures move closer to the de-biased partial fairness assessment 'avg. fair share' and show no differences across communication treatments.

4.2. The impact of communication on initial own claims

While Result 1 is important because it shows that communication increases efficiency and induces payoffs that are closer to partial fairness assessments, it is not obvious how this result comes about. It may be that all contribution types are willing to concede more to the partners after pre-play communication, or that some types change behavior more than others. To obtain information about the origins of the communication effect, we take a closer look at subjects' initial own claim m_i^i and how it compares to the *avg. fair share* c_i^{avg}. The difference between these two variables may be interpreted as a self-serving bias.[20] Recall that m_i^i is not available for the Impartial Division Rule – this is why it is left out in this subsection.

Panel B of Fig. 1 plots, for each contribution type and communication treatment, the mean of m_i^i across procedures in comparison to our fairness benchmarks, giving a general indication of how the initial claims shape our findings regarding the final allocations discussed above. We observe the following: (i) While in NOCOM initial own claims of all contribution types exceed our fairness benchmarks, they decrease significantly in all communication treatments. This points to a lower self-serving bias in own claims when communication is present. Also, it questions the existence of minority-exploiting coalitions, as we will discuss below. (ii) Communication drives high contributors' own claims below their *avg. fair share*, while low and medium contributors still claim more than c_i^{avg}. (iii) Lower own claims lead to increased compatibility with others' claims, thus allowing for large efficiency gains in final allocations with communication, as observed in Panel A.[21]

Table 3 presents further details regarding the reduced self-serving bias. First, consider the mean of the difference $m_i^i - c_i^{avg}$, pooled over all types and mechanisms. Based on this difference, the results suggest that initial own claims are close to *avg. fair shares* in all communication treatments – but not in the NOCOM treatment – implying that the self-serving bias is considerably reduced with communication compared to the NOCOM benchmark. However, at the same time the average correlation coefficient ρ between m_i^i and c_i^{avg} does not systematically increase with communication. It is particularly low in PUBLIC (ρ=0.25, compared to ρ=0.47 in NOCOM). The reason for this discrepancy becomes clear when we disaggregate by contribution type, as shown in the middle section of Table 3. In all treatments with communication, the difference $m_i^i - c_i^{avg}$ becomes negative for the high contributor, the deviation being largest in PUBLIC. For low and medium contributors, the respective difference is reduced compared to NOCOM, but still positive.

Introducing communication thus has a moderating effect on the self-serving bias of low and medium contributors. The largest effect, however, is on high contributors: the self-serving bias here not only vanishes entirely, but initial own claims

[20] Of course, m_i^i may already reflect the incentives a given procedure provides for subjects who are motivated by strategic concerns. The comparison between NOCOM and the three communication treatments keeps these incentives fixed and allows us to focus on the communication effect.

[21] Efficiency will be discussed further in Section 4.4.

Table 3
Self-serving bias: Deviation of inital own claim m_i^i from fairness benchmark *avg. fair share* c_i^{avg} across communication treatments (in % of cake size).

	NOCOM	PRIVATE	PUBLIC	CHOICE
POOLED ANALYSIS				
Mean deviation $m_i^i - c_i^{avg}$	3.47	0.54 ***	0.22 ***	0.51 ***
Spearman's ρ	0.47	0.49	0.25	0.41
BY CONTRIBUTION TYPE				
Mean deviation $m_i^i - c_i^{avg}$				
Low	5.19	2.03 **	1.64 ***	1.46 ***
Medium	2.94	1.06 **	1.06 **	1.85
High	2.28	−1.47 ***	−2.03 ***	−1.76 ***
BY PROCEDURE				
Mean deviation $m_i^i - c_i^{avg}$				
Div.$	4.39	1.19 ***	0.00 ***	0.40 ***
NashDem.	5.05	0.39 ***	0.59 ***	0.65 ***
Barg.	0.98	0.04 ***	0.08 ***	0.49

*** (**) [*] indicates that the comparison to NOCOM is significant at 1 (5) [10] level in OLS regression with mean difference as dependent variable, controlling for group composition and contribution type, or mechanism, respectively; robust SE are clustered on the group level.

are below the *avg. fair share*. Table A.3 in the appendix shows that this result continues to hold when we consider each type and procedure separately. Finally, a comparison across procedures shows that in bargaining the self-serving bias is lowest in NOCOM, and decreases further with communication. This is not self-evident, as the static mechanisms provide built-in incentives not to overstate the own claim, and furthermore, they offer no possibility to modify the initial claim, while bargaining is dynamic and thus offers can be corrected in later rounds. On the other hand, bargaining is the only procedure where partners decide directly over others' proposals. This reduces initial own claims even in the absence of other communication channels, thus explaining why payoff shares are closest to c_i^{avg} in bargaining (see Table 2).

One explanation for the less pronounced decrease in low and medium contributors' own claims may be that these types engage in collusion. Now, if collusion indeed played a decisive role for behavior in our procedures, we would expect initial own claims to be significantly influenced by the type of communication channel available. For the large majority of the data, such an influence seems to be absent. In particular, there is no significant difference in initial own claims between PUBLIC and PRIVATE (Wilcoxon rank sum test, WRS: $p = 0.28$) as well as between PUBLIC and CHOICE (WRS: $p = 0.57$), where in both comparisons the second protocol would explicitly allow for strategic demands. Importantly, there is also no such difference if we consider initial own claims m_i^i for each contribution type in every procedure separately. In fact, as we will analyse in more detail in subsection 4.5, an explicit conspiracy via chat takes place very rarely. Subjects rather seem to use communication in order to establish what constitutes a fair division. Consistent with this conjecture, the private communication channel in CHOICE is used in less than 8% of the cases.

Our result that private communication is rare in treatment CHOICE seems to contradict earlier findings by Cason et al. (2012) who investigate a setting in which two groups compete in a weakest-link game by expending costly effort. The authors find that when the groups have the choice between inter- and intra-group communication, half of the groups use intra-group communication to compete more aggressively against the rival group while the other half use inter-group communication to cooperate with the rival group. It is difficult to attribute the differences in results to a single cause because the settings are very different. For example, in Cason et al. there is a clear (exogenously given) distinction between the in-group and the out-group. Furthermore, in-group and out-group communication have very different potential benefits (coordinating within-group effort vs. avoiding destructive competition between groups). In our environment, the boundary between in-group and out-group is rather blurred, as each other group member is to some degree a rival (because the partners' shares cannot sum up to more than the value of the cake) and to some degree a partner (because disagreement over the shares leads to a loss in efficiency under all our procedures). Here, private communication with the intention to collude requires defining one other group member as the potential (coalition) partner and the other as the rival. And it also requires trusting the prospective partner that he is willing to collude at the expense of the rival. Our data suggests that subjects are unwilling to collude in such an environment – while they might be willing to collude at the expense of others if there is a clearly defined boundary between the in- and the out-group.

We summarize this subsection's findings as follows.

Result 2. Communication has a moderating effect on the self-serving bias in initial own claims, independent of the communication channel. High contributors make initial own claims below their avg. fair share, which increases compatibility of claims and thus also efficiency. Overall, initial own claims are similar in all communication treatments, suggesting that significant attempts of forming minority-exploiting coalitions are not made even when the environment was favorable.

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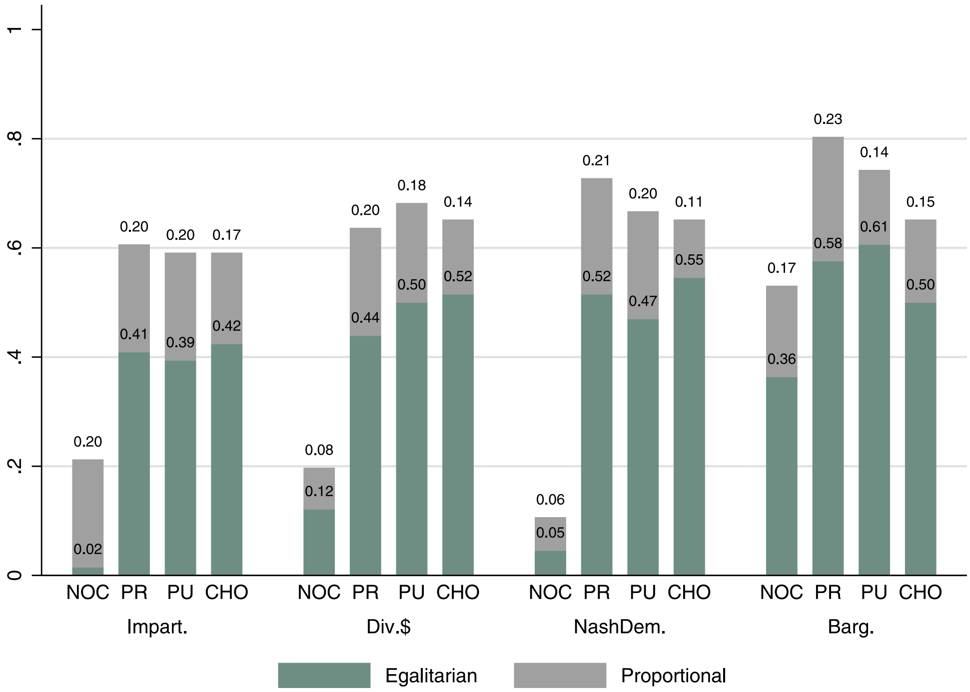

Fig. 2. Conformity of realized payoff shares with known fairness norms *Note*: For each communication treatment (NOCOM, PRIVATE, PUBLIC, CHOICE) and procedure (Impartial Division, Divide-the-Dollar, Modified Nash-Demand, Bargaining) we plot the fraction of groups where the vector of payoff shares matches a fairness norm.

4.3. Conformity with prominent fairness norms

This section considers the role of well-known fairness norms for behavior in the subjective claims problem. If communication serves as a coordination device, we would expect more conformity with a given fairness norm within groups. At the same time, multiple fairness standards can plausibly be applied in our setting, and subjects may tend to refer to the fairness norm that benefits them most, as suggested by Cappelen et al. (2007).[22] In our previous study (see Gantner et al. 2017) we found support for this idea: when subjects were asked what they consider a fair division, low contributors tended to report fair shares consistent with the egalitarian standard, while the proportional standard was more prevalent for high contributors. In the current setup, we ask whether such self-serving application of norms is also reflected in outcomes. Andreoni and Rao (2011) present evidence indicating that pro-social behavior activated through social cues such as communication is mainly driven by a willingness to maintain a positive self-image or a positive social image. We might thus expect that self-serving reference to norms increases when a private communication channel is available.

To assess whether a group adheres to a certain norm, we therefore consider payoff vectors $\mathbf{s} = (s_A, s_B, s_C)$ on the group level. Fig. 2 plots the frequency of payoff shares that are consistent with the proportional or egalitarian norm for each procedure and communication treatment.

We find that communication induces a remarkable increase in the conformity of realized payoff shares with known fairness norms, in particular with the egalitarian standard. As Fig. 2 shows, there are some differences across procedures: (i) For Bargaining, which is the only dynamic procedure where subjects interact during the actual division process, payoffs in NOCOM yield by far the largest correspondence with fairness norms amongst all procedures – over 50% of all payoff allocations correspond to either an egalitarian (36%) or a proportional (17%) standard. Thus, dynamic interaction in the face of conflict, even if limited to stating concrete proposals, seems to support an agreement according to known norms. With communication, agreement on a given norm can be explicitly discussed, and we find that egalitarian divisions increase further to over 50%, while the number of proportional divisions does not change considerably. (ii) The Impartial Division Rule and the Extended Divide-the-Dollar Rule yield similar shares of payoffs consistent with fairness norms. The former, however, seems to make relative contributions more salient by its defining property of asking only for a report on the ratio of the partners' shares, as we observe 20% of proportional divisions in NOCOM, which is more than in any other procedure, and virtually no egalitarian divisions. Communication leads to a pronounced increase in the share of egalitarian outcomes but does

[22] This may be viewed as an interpretation of "moral wiggle room" (see Dana et al., 2007); the idea that people want to appear fair to themselves and to others is supported by various studies on fairness (see Rodriguez-Lara and Moreno-Garrido (2012), or Feng et al. (2013)).

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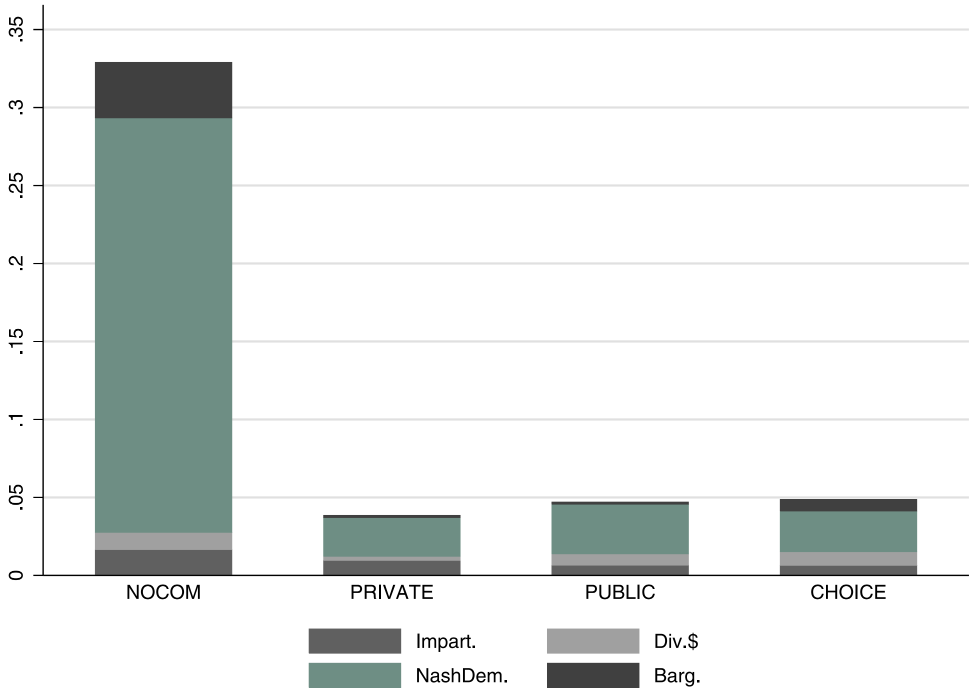

Fig. 3. Efficiency loss over treatments *Note*: For each treatment this graphs sums the average efficiency loss through disagreement for each of the four procedures as a fraction of the cake.

not increase conformity with the proportional standard under this mechanism. (iii) The Nash-Demand Rule has the lowest share of final allocations consistent with a fairness norm, which is due to the frequent occurrence of fines and the resulting distortion of payoffs observed for this procedure in NOCOM. With communication, we observe a similar share of proportional and egalitarian outcomes as in the other static procedures.

Result 3. Without communication, bargaining is the only division procedure that yields a substantial proportion of 36% of egalitarian divisions and a large proportion of 53% of divisions consistent with either the egalitarian or the proportional standard. Allowing for communication increases the frequency of outcomes consistent with either the egalitarian or the proportional standard in all division procedures and for all three communication protocols. The effect is particularly strong for the consistency with the egalitarian standard under the three static mechanisms (where the increase amounts to more than 30 percentage points under each communication protocol).

4.4. Efficiency

Recall that inefficiencies are possible in each of the considered procedures; they are caused by disagreement, which ultimately leads to a loss of a fraction of the cake size. In the Modified Nash Demand Rule and the Extended Divide-the-Dollar Rule, own claims summing up to more than S result in a fine. In the Extended Divide-the-Dollar Rule own claims summing up to less than S also result in an inefficiency. In the Impartial Division Rule, an inconsistency across partners in the reported relative shares results in an efficiency loss. Finally, in Bargaining, delayed agreement is fined through discounting. Fig. 3 sums the average efficiency loss for each procedure in each of the communication treatments. Clearly, efficiency increases sharply with communication. For the Modified Nash Demand Rule, which displayed the largest inefficiency of about 25% of the cake size in NOCOM, we see extensive efficiency gains (WSR: $p < 0.01$, comparing each communication treatment to NOCOM). Also, for Bargaining, the efficiency loss in NOCOM is reduced in all communication treatments, which is due to a significant reduction of bargaining duration: While only about 70% of the groups reached immediate agreement in NOCOM, this number increases to 94% in CHOICE and to 98% in PRIVATE and PUBLIC.[23] For the Impartial Division Rule and the Extended Divide the Dollar Rule efficiency is already over 98% in NOCOM. It is further increased in each communication treatment for the former (WSR: $p < 0.01$), while for the latter, efficiency is only increased in PRIVATE (WSR: $p < 0.05$). To sum up:

[23] The increase in efficiency for the Modified Nash Demand rule and for Bargaining in the treatments with communication suggests that our particular parameter choice for the discount factor δ and the punishment factor a does not play a major role for the size of efficiency loss.

Result 4. Efficiency is strongly increased with communication, with rather small differences across the communication protocols. While the Impartial Division Rule and the Divide-the-Dollar Rule show good results already in NOCOM, Bargaining and in particular the Modified Nash Demand Rule can eliminate almost all of the efficiency losses observed in NOCOM through communication.

5. Chat analysis

Next we address the question how the content of communication shapes behavior and outcomes. Specifically, we present a content analysis of the chat messages, focussing on the following questions: (1) Why does pre-play communication foster final divisions more in line with fairness norms, especially equal splits, when the result of this communication is not binding in any way? (2) Do all of our communication channels solely foster agreement, or is there also some evidence for attempted formation of minority-exploiting coalitions or other forms of self-serving behavior in the message content? (3) Are there regularities in the chat dynamics regarding how agreements are formed and disagreements resolved in groups?

We first present the results focussing exclusively on the *chat content*. Based on that data we address questions (1) and (2) above by identifying the topics of the conversations – what kind of proposals were made, whether collusion was attempted, and whether the contribution type matters for the chat content. To address question (3), we then present the results of a *chat dynamics* analysis, taking into account the sequence of proposals and reactions in the groups, thereby identifying patterns of how agreements in groups were formed.

As is common for this type of analysis (see, e.g., Cooper and Kagel, 2005, or more recently Leibbrandt and Sääksvuori (2012) and Cason et al. (2012)), we employed research assistants (coders), who where trained to independently code the messages into a set of binary variables, i.e. a system of content categories. These were defined based on theoretical interest and empirical relevance, scanning through parts of the communication data. For the *chat content* analysis, two coders considered the entire communication in a chat window preceding the decisions for a given mechanism as a coding unit. They marked a chat content coding category for an individual subject if *any* message in the chat window of that subject matched the corresponding category, irrespective of the time it occurred during the chat. Therefore, for this part of our analysis we have data on the individual level on the chat content for each of the four mechanisms, but no information regarding the timing of chat contents. To address our reseach question (3), we complement the *chat content* analysis by a *chat dynamics* analysis, for which two (different) coders considered each separate chat line a subject entered in any of the available channels as a coding unit. For this part of our analysis the coders were asked to mark all coding categories that apply to a given chat line, thus giving us information about the chat dynamics.

5.1. Chat content analysis

Chat categories and frequencies. Table A.4 and A.5 in the appendix report for each content category the relative coding frequency in each communication treatment by procedure and by contribution type (organized by frequency). The tables include Cohen's κ, a common measure of inter-rater agreement, which shows a fair amount of overall agreement between coders: The average κ is 0.55, which is comparable to the findings in Leibbrandt and Sääksvuori (2012), with considerable variation over categories.[24]

Overall, the most commonly used argument is a “Concrete” division proposal. It is used to accompany a well-known fairness norm (correlation with the egalitarian standard “Equal” is 0.53 and with the proportional standard “Prop.” is 0.46, t-test: $p < 0.001$). Besides the category that collects statements indicating a final “Agreement”, categories regarding fairness norms are the most frequent categories, which also show the highest κ. Tables A.6 and A.7 in the appendix display the effect of mentioning an egalitarian (“Equal”) or proportional (“Prop.”) division in the chat on the probability of observing a egalitarian or proportional final payoff vector in each of the four procedures. The dummy variables “Equal” and “Prop.” show that the corresponding (opposite) division is considerably more (less) likely when a fairness standard is explicitly mentioned. While for Bargaining the marginal effect of “Equal” is largest, the effect of “Prop.” is largest for the Impartial Division Rule. This indicates the prominence of the respective fairness norm for the corresponding procedure and confirms that communication induces a large increase in the conformity of final allocations with fairness norms.

As already conjectured earlier, “Collusion” is discussed or proposed very rarely – the relative frequency of this category is below 4% in each procedure. Thus, the widespread concern that fair division mechanisms are susceptible to collusion (see Tideman and Plassmann (2008), for instance) seems to overestimate the empirical relevance of collusion attempts. Instead, subjects pass along the same information to both partners when public information is infeasible, which obviously counteracts collusion. This is captured in the category “Common knowledge”, which is one of the top five categories by frequency in PRIVATE (39%). A further look into collusive attempts shows that such attempts take place significantly more often in the Divide-the-Dollar Rule and the Impartial Division Rule, as compared to the other two procedures (χ^2- test: $p < 0.02$). This is in line with our conjecture that the Unanimity Bargaining Rule as well as the Modified Nash Demand Rule do not leave much room for collusive behavior. And finally, while there is generally no evidence that a particular pair of contributors engages in strategic conspiracy more often than others, the high contributor is involved more often than other contribution types (χ^2-test: $p < 0.05$).

[24] We do not report categories if their frequency is below 0.05 or their κ is below 0.1, except for “Collusion”, as it is one of our special interest topics.

Table 4
Chat Content analysis: Mixed effects regression of "Payoff" on chat content categories and treatment variables.

Fixed effects			
Intercept	11.320 ***	Impart.	−0.138
PUBLIC	0.060	Div.$	0.027
CHOICE	−0.004	NashDem.	−0.359
Collusion	1.967 ***	Mechanism	−0.056
PUBLIC × Collusion	0.367	Impart. × Mechanism	0.602
CHOICE × Collusion	1.992 ***	Div.$ × Mechanism	−0.244
Med. Contrib.	1.719 ***	NashDem. × Mechanism	0.288
High Contrib.	3.845 ***	Efficiency	−0.149
Equal	0.892 ***	Common Knowl.	−0.049
Equal × Med. Contrib.	−1.028 ***	Concrete	0.015
Equal × High Contrib.	−2.231 ***	Real	−0.053
Prop.	−0.952 ***	Fairness	0.029
Prop. × Med. Contrib.	0.565 **	Agreement	0.151
Prop. × High Contrib.	2.221 ***	Equal support	−0.134
Team	0.389 *	Prop. support	−0.097
Random effects			
Group	15.885		
Residual	2.979		
No. of Obs./ Group decisions	2376/ 792	Log likelihood	−5790.442
Wald χ^2	1410.8	LR test: $\bar{\chi}^2$	1183.97
$P > \chi^2$	0.000	$P \geq \bar{\chi}^2$	0.000

We regress the payoff in points over each of the four procedures on various regressors including all of our content categories as fixed effects, controlling for a random effect on the group level. The LR test supports inclusion of the random effect. Interacted variables are parametrized as simple effects of the first at each level of the interacted variables. Treatment NOCOM is omitted.

Effects of chat categories on payoffs. Table 4 presents a mixed model regressing the payoff over each of the four procedures on all of our content categories as fixed effects and a random effect on the group level, to account for interdependence between the three members of a partnership.[25] First, the interaction of "Collusion" with PRIVATE and with CHOICE significantly increases payoffs. Thus, although collusion attempts are indeed rare in all treatments, they are highly effective. In line with intuition, collusion only has a positive effect on payoff if a private communication channel is available. Indeed, "Collusion" × PUBLIC is far from being significant, and in CHOICE, where we can distinguish the channels, "Collusion" was exclusively used in the private chat window. Second, the coefficients on the interaction of "Equal" and "Prop" with contribution types confirm our findings from Section 4.3: "Equal" ("Prop") increases (decreases) the payoff of the low contributor, whereas it decreases (increases) the payoff of the medium and the high contributor, leading to a more (less) egalitarian division. While most of the other content categories do not significantly affect payoffs, one further important argument is expressing empathy within the "Team". In line with previous findings (see, e.g., Andreoni and Rao, 2011) a higher group identification such as "I really feel that we are one good group" is generally associated with a higher payoff.

More details on the significance of "Team" in the chat are provided by the probit regression of "Team" on the other content categories in Table A.8 of the appendix. Talking about an egalitarian division indeed significantly increases the probability of "Team" expressions, while mentioning proportionality achieves the opposite. Talk about "Fairness" and signalling an "Agreement" are positively associated with "Team"; the same holds for "Efficiency". Again, this is in line with former research findings that an enhanced group identity fosters egalitarian divisions and leads to more agreement and efficiency (Chen and Li, 2009; Klor and Shayo, 2009). The largest effect is found for "Collusion", whose occurrence decreases the probability of positive "Team" expressions.[26]

Effect of communication channel. While the allocation data does not indicate a self-serving bias in the choice of fairness norms of the different contribution types, we do find evidence for behavior driven by "moral wiggle room" in the chat protocols. Importantly, the prevalence of this kind of behavior depends on the communication channel available. In line with the idea that subjects want to maintain a positive self-image and "appear nice" vis-Ã -vis the group, the probability that low contributors asks for the self-serving egalitarian division is only 25% in PUBLIC, but 48% in PRIVATE. Also, the instances that indicate support for the egalitarian division ("Equal support") increase from 30% in PUBLIC to 45% in PRIVATE (WRS: $p < 0.001$ for both comparisons). Correspondingly, high contributors propose (support) the self-serving proportional division in only 30% (24%) of the cases in PUBLIC, but in 40% (30%) in PRIVATE (WRS: $p < 0.01$ for proposals and $p = 0.07$ for support)).

[25] Assuming that coders' judgements are independent, errors across coders are independent, and we can use the average of their codings to reduce the total error.

[26] Though very frequent, the two categories "Concrete" and "Common Knowledge" yield no significance when they are included in this regression.

The option of choosing between private and public communication channel in CHOICE provides further evidence for subjects' moral conflict between the self-serving fairness norm and the socially most salient norm in the face of the group, which seems to be the egalitarian norm. Noting that the private channel, which facilitates self-serving behavior, is used for only 8% of the messages in CHOICE, we still observe that the relative frequency of proposing an egalitarian division is higher in the public (11%) than in the private window (6%, χ^2 test: $p < 0.02$). By contrast, the relative frequency of proposing a proportional division is higher in the private than in the public window (15% vs. 9%; χ^2 test: $p < 0.01$).[27] Also, there are virtually no collusive attempts in the public window, whereas there is practically no indication of a positive group identity ("Team") in the private window. Finally, there also is very little "Agreement" in the private (1.9%), but significantly more in the public window (12.4%, χ^2 test: $p < 0.01$)

We summarize our results from the *chat content analysis* as follows.

Result 5. The chat content analysis shows that the most commonly used argument is a concrete division proposal in line with either the proportional or – more frequently – the egalitarian standard. Collusion attempts are generally rare in all treatments, although they are highly effective. Comparing the two communication channels we see that selfish motives and (in rare cases) collusion become apparent when private communication channels are used, while group identity and agreement are emphasised in the chat content with the public channel.

The following subsection will focus on the chat dynamics to understand how agreements in a group come about, how disagreements are resolved and which kind of proposals are likely to prevail.

5.2. Chat dynamics analysis

Dynamic chat categories, frequencies and content exchanged. For the chat dynamics analysis our coding unit is a chat line, since we are interested in which order the chat content appears. To assess the impact of the first proposal in the chat on the final agreement we define the categories "first equal" and "first prop". "First equal" is marked for an individual if the respective chat line contains the first proposal in the chat and if the proposal is egalitarian. If there were other proposals before, possibly by the same subject, then this category is not marked. "First prop" is marked if the respective chat line is a first proposal in the chat and if it is either proportional or unequal but respects the order of contributions. Responses and subsequent proposals to this first proposal are coded as "resp agree" when the immediate response to this proposal is to agree, "resp more equal" when a responder asks for a more egalitarian division, or "resp unequal" when a subject insists on a proportional division in the course of the chat in a subsequent proposal. This way of coding the content allows us to work with the data collapsed on the individual level (as in the previous subsection).

Table A.9 in the appendix reports the relative coding frequency for each content category of the chat dynamics analysis in each communication treatment and procedure (organized by order of possible occurrence during the chat) as well as Cohen's κ.[28] The average κ is 0.87, implying a large agreement over these categories. We have two content categories – "agree on first" and "agree on last" – that have to be evaluated on the group level, since the assignment to these categories is not unique to a chat line and individual.[29] As a measure for how much content is exchanged within groups, we use the total number of chat lines within a group and subtract the number of lines coded as "no content" (i.e. text that is not considered relevant for the experiment). We have an average of about 10 relevant chat lines per group in PUBLIC and also in the public channel of CHOICE. In PRIVATE we add the chat lines of all three chat windows, and we find an average of 16 relevant chat lines per group of three. Clearly, in PRIVATE subjects communicated more, since they had to chat separately to each of their partners. Interestingly, the share of relevant content is 78% in PRIVATE, but only 62% in PUBLIC and 66% in CHOICE (65% in the public and 72% in the private window). PUBLIC is least efficient in terms of communication contents (WRS: $p < 0.001$ for pairwise comparisons).

Dynamics of proposals and responses. The two different communication channels have an impact on the course of communication. Table 5 shows the distribution of egalitarian and proportional offers that were expressed as the first proposal during the chat, on which the remainder of the chat is based. About one half of all first proposals voiced in each treatment is egalitarian, while proportional first proposals occur less frequently.[30] There are significantly more proportional first proposals in PUBLIC compared to PRIVATE (χ^2-test: $p < 0.01$). We do not find differences regarding the contribution type of the subject who takes the initiative by making a first proposal. However, when we take into account which type of first proposal was made, we find a difference: if the first proposal is egalitarian, it originates from a low contributor in 37% of the cases in PRIVATE, but only in 27% in PUBLIC and in 28% in CHOICE, where the public channel was mostly used.

[27] Moreover, 39% (45%) of the proportional (egalitarian) proposals in the private window originate from the high (low) contributor, compared to 24% (25%) from the low (high) contributor. This finding should, however, not be overinterpreted, since the overall number of observations in the private window is relatively low, as stated above.

[28] Since it is important to understand that the coders agree on what was the first proposal, the response to this first proposal etc., we apply Cohen's Kappa to the extensive data set where the unit of coding is a chat line.

[29] We did have three further categories – "compromise", "followlead" and "2 of 3 agree". However, they were marked extremely rarely (below 2%), and we thus dropped them from the analysis.

[30] The numbers in Table 5 represent the relative frequencies out of all possible occurrences, e.g. we have a relative frequency of 0.51 for "first equal" in PUBLIC, because we observe 135 egalitarian first offers in the 792/3=264 groups.

Table 5
Chat dynamics: offers, responses and agreements across treatments.

Category	PRIVATE	PUBLIC	CHOICE
First equal	0.49	0.51	0.46 (0.52)
Resp agree	0.80	0.66	0.80 (0.81)
Resp unequal	0.06	0.10	0.06 (0.06)
Agree on first	0.29	0.78	0.85 (0.87)
Agree on last	0.02	0.07	0.04 (0.04)
First prop	0.38	0.46	0.39 (0.42)
Resp agree	0.63	0.49	0.66 (0.67)
Resp more equal	0.11	0.16	0.11 (0.11)
Resp unequal	0.12	0.24	0.12 (0.12)
Agree on first	0.24	0.74	0.69 (0.75)
Agree on last	0.02	0.15	0.07 (0.06)

Numbers are shares of all active windows (PRIVATE: $N = 1545$, PUBLIC: $N = 792$, CHOICE: $N = 888$, of which 772 use public channel and 65 use both channels. Numbers in parenthesis in CHOICE refer to observations in public channel.)

Egalitarian first offers coming from high contributors are more frequent in PUBLIC (39%) compared to PRIVATE (34%). The origin of an egalitarian first offer thus depends on the contribution type and the communication channel (χ^2-test: $p < 0.1$). In PRIVATE, low contributors make egalitarian first offers significantly more often than the other two types (Kruskal-Wallis test: $p < 0.05$), which supports the idea of using a self-serving fairness norm. On the other hand, high contributors do not ask for proportional distributions more often than other types (Kruskal-Wallis: $p = 0.89$ in PRIVATE, $p = 0.43$ in PUBLIC).

The outcomes of the NOCOM treatment showed that different views exist regarding what constitutes a fair division. Given that we actually found substantial shares of both egalitarian as well as proportional first offers made by different contribution types, one would expect a considerable amount of disagreement with the first offer, since groups are composed of heterogeneous contribution types with different incentives regarding the division. If we consider disagreements with any kind of first proposal, we find significant differences over treatments (χ^2-test: $p < 0.01$): in PRIVATE and CHOICE there are 16% of explicit disagreements with any given first proposal, while it is 29% in PUBLIC. Recall that in CHOICE over 90% of subjects use only the public channel, therefore this difference is unexpected. Table 5 contains information on whether disagreements are equally likely for each kind of first proposal. We find a very large proportion of support for egalitarian first offers (80% in PRIVATE, 66% in PUBLIC, and 80% in CHOICE). There is overall less, but still considerable support for proportional first offers (only about one half of the potential responders agree in PUBLIC, about two thirds in PRIVATE and CHOICE). Fewer proportional first offers combined with lower agreement rates compared to more egalitarian first offers with higher agreement rates help explain why we find significantly more realized payoff shares that correspond to the egalitarian norm as displayed in Fig. 2.

The reference to a self-serving fairness norm is also visible in subjects' responses to first offers during the chat. Low contributors agree significantly more often to egalitarian first offers in PRIVATE compared to PUBLIC, while the opposite is the case for high contributors (χ^2-test: $p < 0.1$), and similar results hold for proportional first offers, where high contributors agree less and large contributors more frequently in PRIVATE.

Reaching agreements and resolving disagreements. Agreement rates for both kinds of first proposal are significantly larger in CHOICE than in PUBLIC, in particular, if we compare only observations from the public channel (χ^2-test: $p < 0.01$). Subjects in CHOICE show less inclination to have discussions over a proposal. The private channel is mostly left unused, in favor of a group-oriented outcome, with the result of increased support for any kind of group decision in CHOICE. By contrast, in PUBLIC, where the public channel is the only one available, explicit disagreement to the first proposal is more frequent than in any other treatment. When the first proposal is proportional, we have the largest share of disagreements ("resp more equal": 16% in the lower half of Table 5) in this treatment. Furthermore, we find a considerable share of responses insisting on this proposal (measured by the share of 24% for "resp unequal"), which indicates controversial group discussions. The category "agree on first", however, shows that despite the discussions in PUBLIC, about three quarters of the groups agree on the proportional first proposal.

The categories "agree on first" and "agree on last" give an important insight into how agreements are generally reached and disagreements resolved. The main insight here is that about three quarters of all groups agree on the first proposal, no matter what it is. It is thus mostly not a group compromise that we observe – our data rather suggests that it is worthwhile being the first in a group chat to express a proposal, as it is likely supported, no matter whether it is egalitarian or proportional.[31] In CHOICE, the egalitarian first proposal is agreed on in even 85% of the groups, thus making it very likely

[31] Note that in the chat analysis we use the label "proportional" for any proposal in the chat that respects the order of contributions. Therefore, it is no contradiction that we find a considerable share of group agreements on "proportional" division during the chat, whereas the realized payoffs in Fig. 2 do

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that an egalitarian first proposal finds agreement in this treatment. In PRIVATE, these numbers are much smaller, because it is difficult to reach an explicit overall group agreement when only pairwise communication is possible.

The categories “priv cheat” (marked for any attempt to cheat on the third partner), “priv disagree” (marked if the addressed partner responded in a negative way to such a cheating suggestion), and “priv inform” (marked if the third partner was informed about the proposal of the other two) were used to detect attempts of two partners to collude at the cost of the third partner. Confirming our earlier findings in the chat content analysis, we found only rare evidence for uses of the private channel to get an advantage on the expense of the third partner, and also few explicit disagreements with such collusive proposals. On the other hand, trying to inform the third partner about communication of the other two does not help with a group agreement (WRS: $p = 0.16$). Communication here often ends without an explicit agreement. Private communication is thus rather obstructive when group members have the intention to reach an overall agreement.

Effect of chat dynamics on payoffs. Reaching explicit group agreements has a positive effect on realized payoffs when the public communication channel is used (WRS: $p < 0.01$ for both PUBLIC and CHOICE). This implies that explicit group agreement during communication are carried over to individual decisions and outcomes, thus supporting efficiency (in the sense that more of the cake is distributed).[32] In CHOICE, explicit group agreements are observed less frequently when subjects used both communication channels (22% vs. 84% when only the public channel is used) – thus, using both channels is clearly detrimental for a group agreement. This has a negative effect on payoffs in the Nash-Demand game (WRS: $p < 0.05$), but not on overall payoffs (WRS: $p = 0.42$). In PRIVATE, trying to inform the third partner about communication of the other two actually decreases the realized payoff (WRS: $p < 0.05$); as mentioned before, it does not help to establish a group agreement.

Table A.10 in the appendix presents statistical support for our major finding that the first proposal is decisive for the outcome of communication. A logit regression shows the large impact of the first proposal of the chat being egalitarian on the likelihood of observing a realized egalitarian payoff (left half of Table A.10), and the impact of the responses of the other two group members. A unilateral agreement of one of the two responders ($firstequal \times respagree$) also has a positive effect, but a larger effect comes from explicit group agreement ($equal \times agreeonfirst$). Furthermore, when initially a proportional division was proposed, an agreement on the last proposal in this group ($firstprop \times agreeonlast$) has a large positive effect, which implies that the group finally agreed on an egalitarian division. Note that agreeing on any first proposal (*agreeonfirst*) has a negative effect on the likelihood of an egalitarian realized payoff, which is consistent with our observation that agreement on any first proposal is likely, no matter what the first proposal is. Overall, this reduces the likelihood of observing precise egalitarian or proportional realized payoffs, since first proposals are similarly likely to be egalitarian or unequal. Considering the impact of the chat dynamics variables on the likelihood of observing a realized proportional payoff (right half of Table A.10), we find similar importance of the fist proposal being proportional. A unilateral agreement to a proportional proposal in the chat ($firstprop \times respagree$) is, however, not sufficient for observing a final proportional payoff, showing that unequal proposals tendentially find more resistance in groups. Only when all group members agree, this is seen in final outcomes.[33]

Result 6. The chat dynamics analysis shows that the first proposal of a chat is decisive for the group agreement. About three quarters of the groups agree on the first proposal, no matter its shape. Explicit group agreements are reflected in final outcomes. Proposals that are unequal but reflect subjects’ contribution order find more resistance in the group discussion compared to egalitarian proposals.

6. Conclusion

This paper studied the effect of the availability of communication opportunities on the behavior of subjects under four different cake division procedures in an environment where agents have subjective and unequal claims. While theoretical considerations suggest that the availability of private communication channels fosters the emergence of minority-exploiting coalitions, attempts to collude are observed very rarely in our experiment. Efficiency is strongly increases with communication, with rather small differences across the communication protocols. While the Impartial Division Rule and the Divide-the-Dollar Rule show good results already in our benchmark without communication, Bargaining and in particular the Modified Nash Demand Rule can eliminate almost all of the efficiency losses observed in the benchmark through commnication.

The fact that collusion attempts are only rarely observed in our experiment suggests that the susceptibility of fair division mechanisms to collusion is primarily a theoretical problem and less a practical one. One might argue that subtle details in our experimental design raise questions about experimenter demand effects and external validity. For instance, (i) our communication treatments with chat windows might lead to more communication than would occur in a natural environment, and (ii) the fact that our PRIVATE treatment has two chat windows open throughout the communication stage might induce subjects to use both. While it may be the case that our experimental design encourages communication *per se*,

not reflect this large share. Recall that in Fig. 2 we only count allocations as proportional that are precisely consistent with the proportional standard as defined in Table 1.

[32] This is in particular true for the Nash-Demand game and the Divide-the-Dollar game, which are precisely those with larger efficiency losses in PUBLIC and CHOICE as seen in Figure 3.

[33] Overall, coefficients here are smaller and the model explains less overall. The worse fit of the model may be due to the fact that there are many quasi-proportional outcomes, which are not considered in the dependent variable “proportional payoff”. Still, our chat dynamics variables (which include proposals that precisely fit the proportional norm) show that they capture the systematic chat dynamics described above.

we do not see any reason why it should induce more cooperative (group-friendly) communication contents as opposed to more collusive contents.[34]

Overall, the differences across agents in realized payoff shares are largely reduced with communication. This indicates that different contributions towards the jointly produced cake, which induce the unequal claims, play a smaller role when communication allows subjects to discuss potential divisions before making their decisions. Fairness norms gain importance with communication, in particular the egalitarian standard.[35] High contributors seem to be willing to bear the cost of this distributive choice, despite their general view that a fair division should take individual contributions into account. Evidence from a chat content analysis suggests that communication shifts subjects' attention from the individual to the group level. Analysing chat dynamics reveals that while egalitarian proposals find the largest support in groups, *any* first proposal made in a group chat is likely to find overall agreement. Explicit group agreements are also reflected in final outcomes. Subjects seem to care about a positive social image vis-à-vis the group, reducing the self-serving bias in the choice of norms (such as the proportional norm for high contributors) – in particular in the treatment with public communication.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.jebo.2019.09.015.

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[34] For example, the fact that in PRIVATE there are two chat windows open (and not only one) might induce participants to use both. But we see no reason why it should induce participants to write the same text in both windows, as we often observed.

[35] There are at least two possible explanations for the finding that communication leads to a higher share of outcomes consistent with one of the fairness norms: one is the increased saliency of the fairness norms with communication, and the other is that subjects learn to understand the incentives of the mechanism. Our analysis does not allow us to distinguish between these two interpretations, however, we find very little support for the latter. For example, with communication we observe more egalitarian divisions for the Impartial Division Rule (compared to NOCOM), i.e. the core feature of this mechanism, which is to evaluate other subjects relative to each other, loses importance. This cannot be due to learning to understand the incentives of this mechanism, but is likely due to the increased saliency of the egalitarian norm with communication.

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